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(54) **HYBRID MECHANICALLY LINED PIPE METHODS AND APPARATUS**

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See application file for complete search history.

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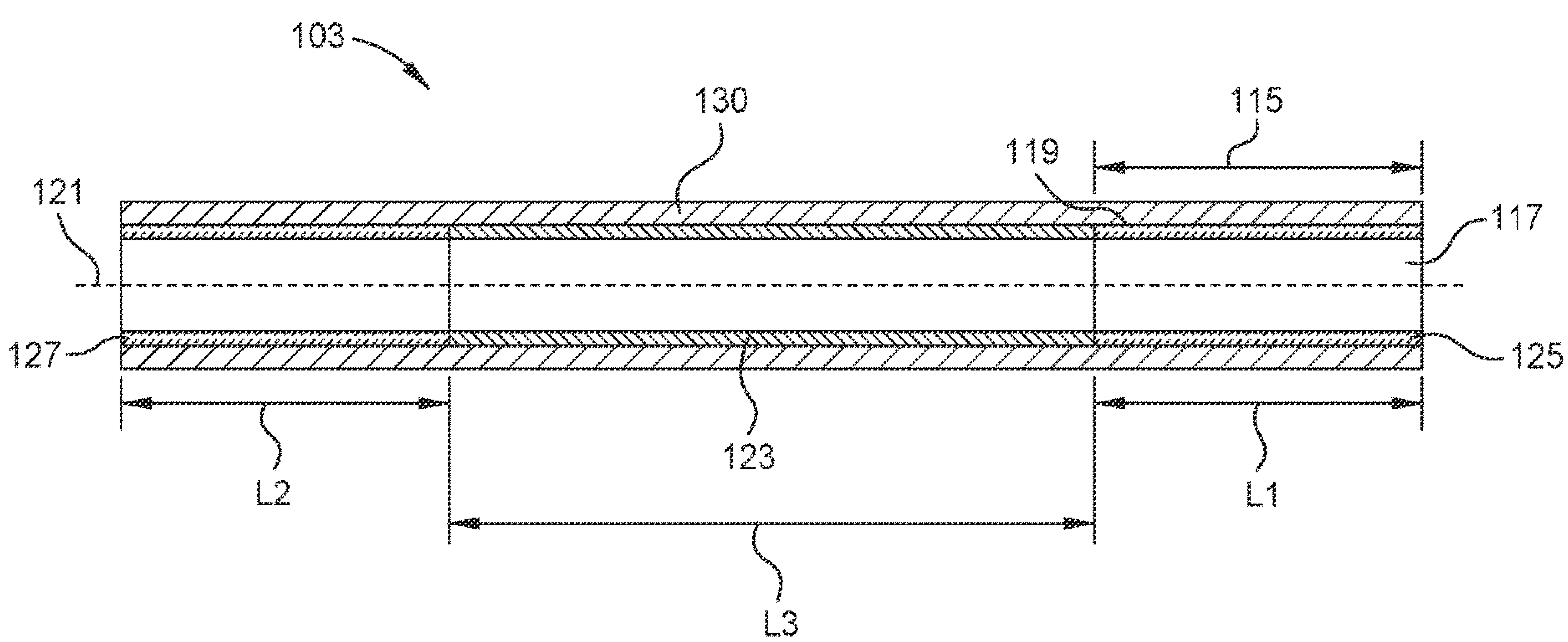
(57) **ABSTRACT**

Aspects of the present disclosure relates to methods of making a hybrid mechanically lined pipe, and apparatus thereof, such as lined pipe used for reeled pipe operations. In one implementation, a method of making a lined pipe for reeled pipe operations includes determining a minimum weld overlay length for a first pipe joint, and providing the first pipe joint. The first pipe joint includes a first end opposite of a second end, a central opening, and an inner surface. The method includes mechanically lining the inner surface of the first pipe joint with a first section of alloy. The method also includes weld overlaying a second section of alloy and a third section of alloy in the central opening and on both sides of the first section of alloy over the minimum weld overlay length to prevent excessive deformation of the mechanically bonded section during reeling operations.

12 Claims, 5 Drawing Sheets



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F16L 58/18 (2006.01)
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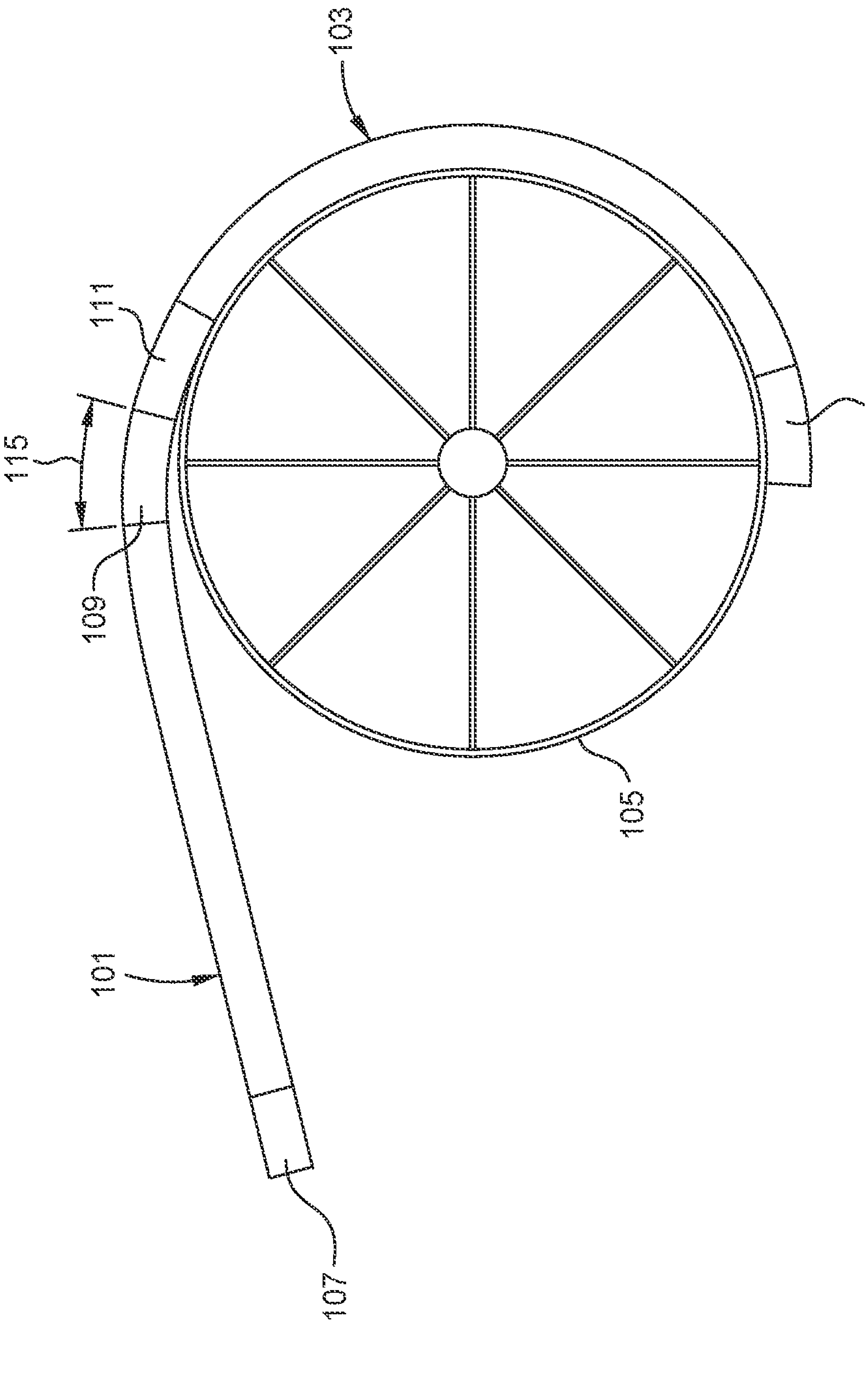

FIG. 1A

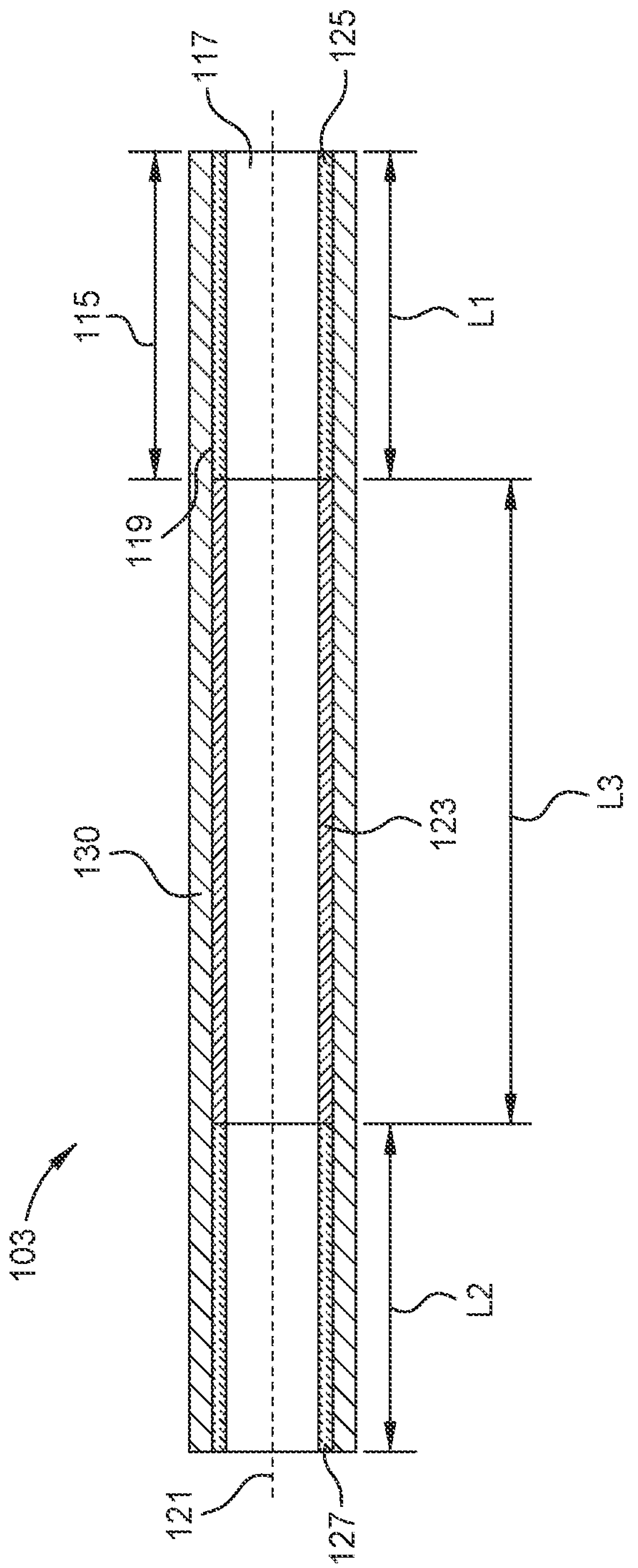

FIG. 1B

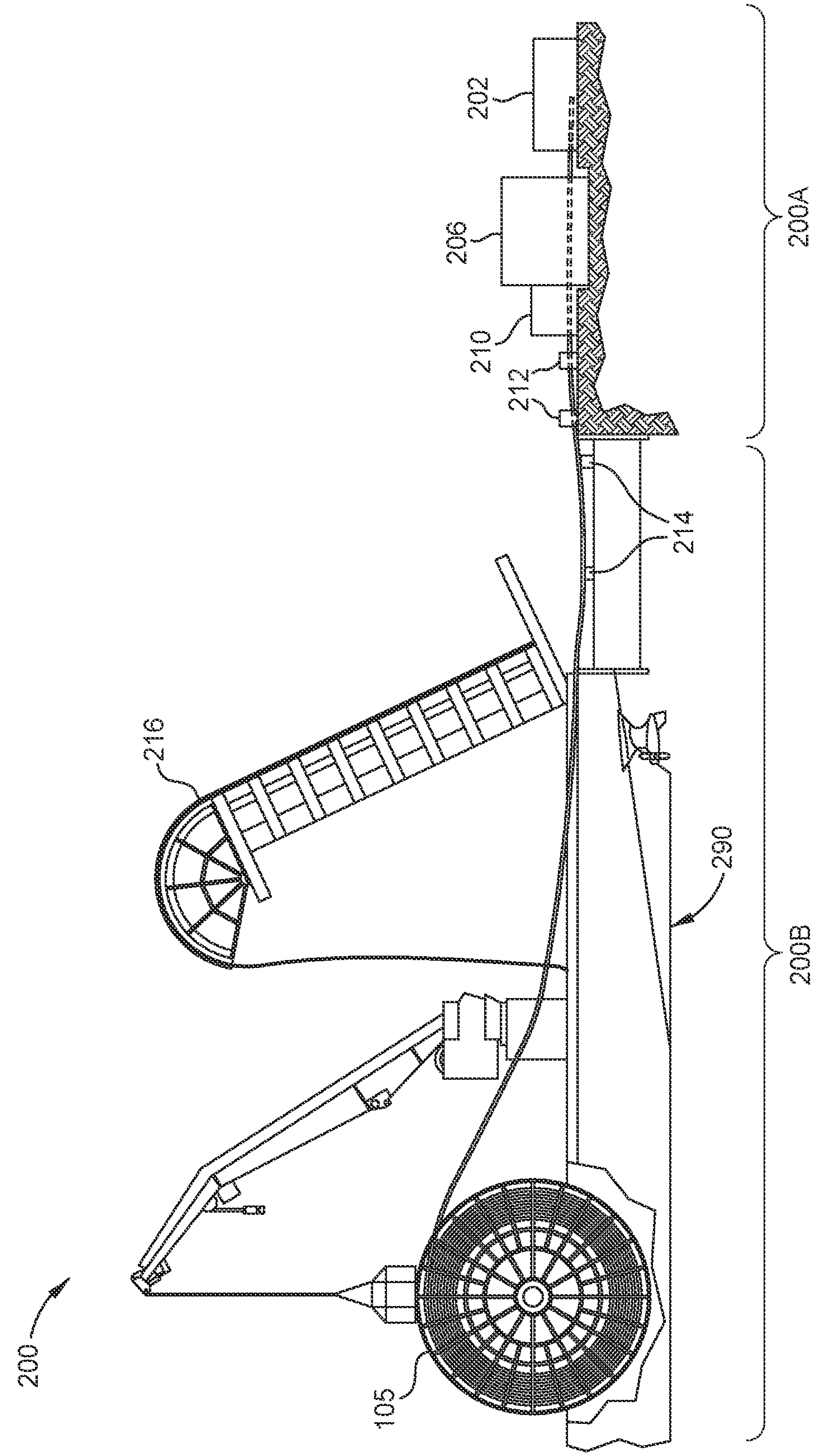

FIG. 2A

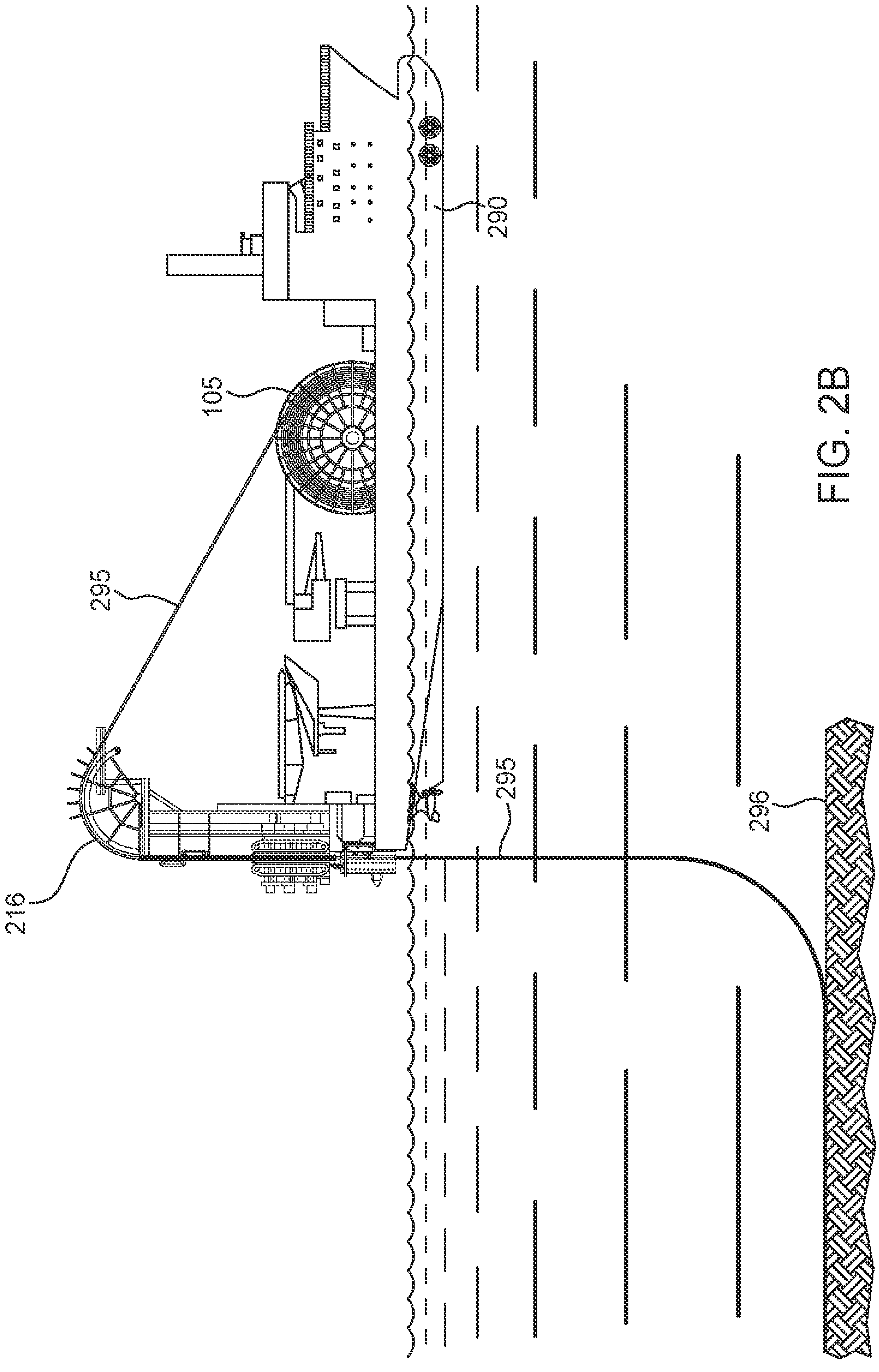

FIG. 2B

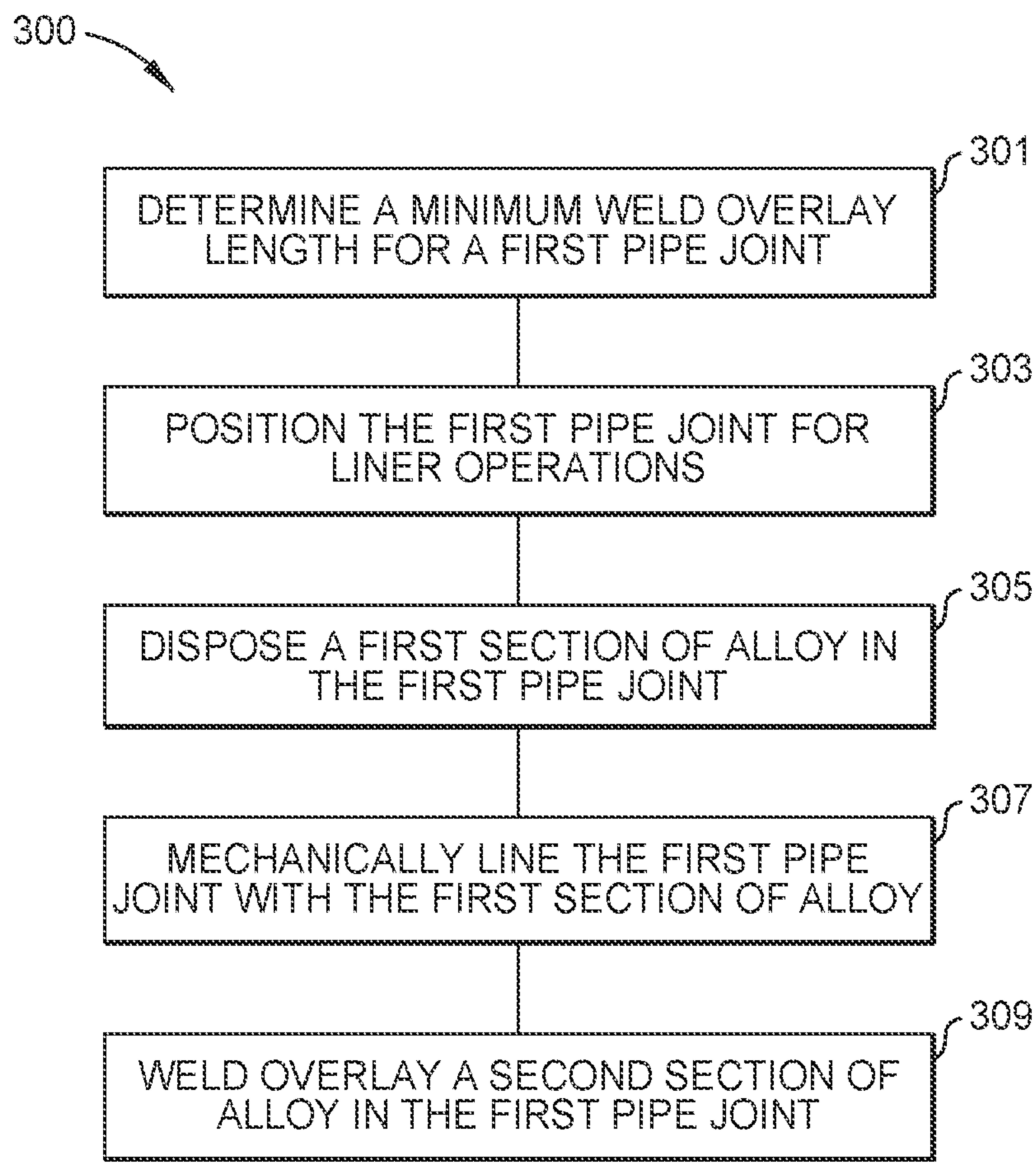
300
DETERMINE A MINIMUM WELD OVERLAY LENGTH FOR A FIRST PIPE JOINT
301
POSITION THE FIRST PIPE JOINT FOR LINER OPERATIONS
303
DISPOSE A FIRST SECTION OF ALLOY IN THE FIRST PIPE JOINT
305
MECHANICALLY LINE THE FIRST PIPE JOINT WITH THE FIRST SECTION OF ALLOY
307
WELD OVERLAY A SECOND SECTION OF ALLOY IN THE FIRST PIPE JOINT
309

FIG. 3

HYBRID MECHANICALLY LINED PIPE METHODS AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. provisional patent application Ser. No. 62/936,179, filed Nov. 15, 2019, which is herein incorporated by reference in its entirety.

BACKGROUND

Field

Aspects of the present disclosure relate to methods of designing and making hybrid mechanically lined pipe, and apparatus thereof, such as lined pipe used for reel-lay operations.

Description of the Related Art

Joints of lined pipe used to make pipelines may have differing properties. The differing properties of the pipe joints can cause wrinkling of the liner in the pipeline when the pipe is bent, such as during reeling and unreeling of the pipe. The wrinkling can create operational issues, for example by inducing pressure drop, inhibiting pipeline pigging, and/or causing fracturing of liner.

Therefore, there is a need for simple and cost-effective methods of making lined pipe that facilitate reduced or eliminated liner wrinkling.

SUMMARY

Aspects of the present disclosure relate to methods of designing and making hybrid mechanically lined pipe, and apparatus thereof, such as lined pipe used for reel-lay operations.

In one implementation, a method of making a lined pipe for reel-lay operations includes determining a minimum weld overlay length for a first pipe joint, and positioning the first pipe joint for liner operations. The first pipe joint includes a first end opposite of a second end, a central opening, and an inner surface. The method also includes disposing a first section of alloy in the central opening of the first pipe joint, and mechanically lining the inner surface of the first pipe joint with the first section of alloy. The method also includes weld overlaying a second section of alloy in the central opening and on a first side of the first section of alloy. The weld overlaying includes welding the second section of alloy to the inner surface of the first pipe joint along a first length that is greater than or equal to the minimum weld overlay length.

In one implementation, a hybrid mechanically lined pipe includes a spool, and a pipeline reeled onto the spool. The pipeline includes one or more pipe joints. Each respective pipe joint of the one or more pipe joints includes a first weld overlay alloy welded to the respective pipe joint along a first length, a second weld overlay alloy welded to the respective pipe joint along a second length, and a liner mechanically lined to the respective pipe joint. The liner is disposed between the first weld overlay alloy and the second weld overlay alloy. Each of the first length and the second length is greater than or equal to a minimum weld overlay length to reduce or prevent wrinkling of the liner.

In one implementation, a pipe includes a pipe joint, a liner mechanically lined to the pipe joint, and a weld overlay

welded within the pipe joint. The weld overlay has a weld overlay length that is greater than or equal to a predetermined length to prevent wrinkling of the liner.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above-recited features of the disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to implementations, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

FIG. **1**A is a partial schematic view of a first pipe joint and a second pipe joint being reeled onto a spool, according to one implementation. This partial schematic view shows only the two consecutive joints which are part of a much longer assembly of joints called a stalk. Several stalks may be joined together and be reeled onto the spool.

FIG. **1**B is a partial schematic view of the first pipe joint illustrated in FIG. **1**A prior to being welded to the second pipe joint and reeled onto the spool, according to one implementation.

FIG. **2**A is a partial schematic view of a reeling system, according to one implementation.

FIG. **2**B is a partial schematic view of the offshore vessel and spool disposed thereon, illustrated in FIG. **2**A, during an offshore pipe-laying operation, according to one implementation.

FIG. **3** is a schematic view of a method of making a lined pipe for reel-lay operations, according to one implementation.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one implementation may be beneficially utilized on other implementations without specific recitation.

DETAILED DESCRIPTION

Aspects of the present disclosure relates to methods of making lined pipe to be used for reel-lay applications. The aspects disclosed herein facilitate reduced or eliminated liner wrinkling of liner inside the pipe during any bending cycle associated with reeling operations, such as reeling or unreeling of the pipe.

FIG. **1**A is a partial schematic view of a first pipe joint **103** and a second pipe joint **101** being reeled onto a spool **105**, according to one implementation. The spool **105** can be referred to as a reel. The first pipe joint **103**, the second pipe joint **101**, and one or more additional pipe joints may be reeled onto the spool **105** and the spool **105** placed on a vessel for conducting reel-lay operations. The pipe joints **101**, **103** may be reeled onto the spool **105** to form a reeled hybrid mechanically lined pipe. The reel may be removable or a permanent piece of equipment of an installation vessel. The first pipe joint **103** and the second pipe joint **101** may be part of a longer pipeline. Pipe joints, such as the first pipe joint **103** and the second pipe joint **101**, are reeled onto the spool **105** to form a reeled pipeline apparatus. The reel-lay operations may take place offshore using the vessel and may include pipe-laying operations where the pipe joints **101**, **103** reeled onto the spool **105** are unreeled from the spool **105** and layed into the ocean, from the vessel, and toward the seafloor to be used as part of oil and gas equipment such as a flowline or a riser. Fluid is flowed through the pipe joints **101**, **103** after the pipe joints **101**, **103** are unreeled from the spool **105**. In one example, the fluid includes production fluids, such as hydrocarbons. In one example, the fluid includes injection fluids. The reeling operation may include all or some of the following operations: reeling the pipe onto a spool, unreeling pipe from the spool, bending the pipe over an aligner, bending the pipe through a straightener, and/or reversal and/or repeating of one or more of the preceding operations.

The first pipe joint **103** includes a first joint section **113** at a first end thereof and a second joint section **111** at a second end thereof. The second pipe joint **101** includes a first joint section **109** at a first end thereof and a second joint section **107** at a second end thereof. The second joint section **111** of the first pipe joint **103** is welded to the first joint section **109** of the second pipe joint **101**. The second joint section **111** is welded to the first joint section **109** prior to initiating bending in the second joint section **111** and the first joint section **109**. The first joint section **113** is coupled to the spool **105** to initiate reeling of the pipe joints. One or more additional pipe joints (e.g., stalks of pipe) may be reeled onto the spool **105**. In one example, a plurality of pipe joints are welded together to form a pipeline that is several kilometers long, and the pipeline is reeled onto the spool **105**.

As illustrated in FIG. **1**A, the first joint section **109** and the second joint section **111** are undergoing bending while being reeled onto the spool **105**. The first joint section **109** and the second joint section **111** may include differing stiffnesses due to the potential for differing properties between the first pipe joint **103** and the second pipe joint **101**. For example, the first joint section **109** and the second joint section **111** may include but are not limited to differing manufacturing tolerances, differing pipe thicknesses, differing diameters, differing mechanical properties (such as yield strengths and/or ultimate tensile strength).

Due to the differing properties between the first joint section **109** and the second joint section **111**, a mechanically lined alloy disposed inside of the first pipe joint **103** and/or the second pipe joint **101** may wrinkle and become at least partially separated from the parent pipe of **103** or **101**. As an example, the differing bending stiffnesses may cause the first joint section **109** of the second pipe joint **101** to be weaker than the second joint section **111** of the first pipe joint **103**. The weaker pipe joint section **109** will bend more than the neighbouring and stronger pipe section **111**. As a result, the weaker pipe section may see an increased bending strain. The relatively increased bending strain causes an increased risk of liner wrinkling. A larger number of times that a pipe undergoes bending and a larger magnitude of bending can each increase the risk of liner wrinkling.

In accordance with aspects of the present disclosure, a minimum weld overlay length **115** (shown in FIG. **1**B) is determined for second and third internal liner sections **125** and **127** such that the second and third internal liner sections **125** and **127** encompass the pipe sections exposed to increased deformations due to differing pipe properties. The lengths of second and third internal liner sections **125** and **127** are defined by the minimum weld overlay length **115** potentially exposed to increased deformation plus optionally additional length accounting for welding process allowances such as cut-out and re-weld. The lengths of the second and third internal liner sections **125** and **127** can accordingly be longer than the minimum weld overlay length **115**.

The minimum weld overlay length **115** is determined using an engineering analysis taking into account all pipe properties variations and the reeling process parameters. The analysis defines the length of pipe at risk for unacceptable wrinkle formation for the application due to the mismatch of properties between two joined pipes. In one example, the engineering analysis uses a computer modeling software such as finite element analysis (FEA).

In one embodiment, which can be combined with other embodiments, the minimum weld overlay length **115** is greater than 70 mm. In one example, the minimum weld overlay length **115** is greater than 300 mm.

In one embodiment, which can be combined with other embodiments, the resultant deformation used to determine the minimum weld overlay length **115** is determined prior to reeling of the pipe for installation by simulating the reeling operation on a test bench. During the simulating, reeling of the first pipe joint **103** and the second pipe joint **101** onto the spool **105** is simulated. In one example, the simulating of the reeling is conducted using computer modeling software, such as finite element analysis (FEA) software. The simulation of the reeling operations uses parameters of the first pipe joint **103**, the second pipe joint **101**, the spool **105**, and other equipment such as an aligner (shown on a tower **216** in FIGS. **2**A and **2**B) and a straightener of the lay vessel. In one example, the simulation simulates bending of the first pipe joint **103** and the second pipe joint **101** during reeling operations and/or unreeling operations. The parameters include but are not limited to spool diameter, pipe inner diameters, pipe outer diameters, pipe lengths, pipe and liner material properties (for example yield strength and/or ultimate tensile strength), straightener settings, reeling tension, reel back tension, mechanical liner thickness, mechanical liner length, weld overlay thickness, and/or weld overlay length.

In one embodiment, which can be combined with other embodiments, the simulating includes simulating a resultant deformation (such as a resultant strain) of the first pipe joint **103** and/or the second pipe joint **101** during the simulated reeling. Using a threshold deformation (such as a threshold strain), the resultant deformation is used to determine the minimum weld overlay length **115**. The resultant deformation is compared to the threshold deformation to determine the minimum weld overlay length **115**. In one example, which can be combined with other examples, the minimum weld overlay length **115** that is determined is a weld overlay length at which the resultant deformation is equal to or lesser than the threshold deformation. In one example, the resultant deformation is determined for each of the joint sections **107**, **109**, **111**, and **113** by simulating the reeling to determine the minimum weld overlay length **115** to be used for each of the joint sections **107**, **109**, **111**, and **113**.

FIG. **1**B is a partial schematic view of the first pipe joint **103** illustrated in FIG. **1**A prior to being welded to the second pipe joint **101** and reeled onto the spool **105**, according to one implementation. The first pipe joint **103** includes carbon steel. The first pipe joint **103** includes a parent pipe **130**, a central opening **117**, and an inner surface **119**. The first pipe joint **103** includes a longitudinal axis **121** extending through a center of the first pipe joint **103**. The first pipe joint **103** includes a first internal liner section **123** disposed in the central opening **117** and axially aligned with the longitudinal axis **121**. The first internal liner section **123** is a first section of alloy including a tube disposed in the central opening **117** that includes a corrosion resistant alloy. The first internal liner section **123** is a liner that is mechanically lined on the inner surface **119** of the parent pipe **130**.

The first internal liner section **123** is mechanically lined to the inner surface **119** by pressuring the central opening **117** with a pressurized fluid to mechanically bond the first internal liner section **123** to the inner surface **119**. The first internal liner section **123** is deformed to bond the first internal liner section **123** to the inner surface **119**. After the first internal liner section **123** is mechanically bonded to the inner surface **119**, a second internal liner section **125** is weld overlaid in the central opening **117** on a first side of the first internal liner section **123**, and a third internal liner section **127** is weld overlaid in the central opening **117** on a second side of the first internal liner section **123**. The second internal liner section **125** is a second section of alloy and the third internal liner section **127** is a third section of alloy. Each of the second internal liner section **125** and the third internal liner section **127** abut the first internal liner section **123** at opposite ends of the internal liner section **123**. Each of the second internal liner section **125** and the third internal liner section **127** includes a corrosion resistant alloy. The second internal liner section **125** corresponds to the first joint section **109** (illustrated in FIG. **1**A) and the third internal liner section **127** corresponds to the second joint section **107** (illustrated in FIG. **1**A).

In the implementation shown in FIG. **1**B, a single pipe joint **103** includes the parent pipe **130** lined by internal liner sections **123**, **125** and **127**. The first internal liner section **123** is mechanically lined and the second and third internal liner sections **125** and **127** are weld overlaid.

Each of the second internal liner section **125** and the third internal liner section **127** is a weld overlay alloy. After the first internal liner section **123** is mechanically bonded to the inner surface **119** and before initiating bending by reeling the first pipe joint **103**, the second and third sections of alloy **125**, **127** are welded to the inner surface to create a metallurgical bond between the sections of alloy **125**, **127** and the inner surface **119**. The second internal liner section **125** is welded to the inner surface **119** along a first length L**1**. The third internal liner section **127** is welded to the inner surface **119** along a second length L**2**. Each of the first length L**1** and the second length is equal to or greater than the minimum weld overlay length **115** that is determined as discussed above. The minimum weld overlay length **115** is illustrated as linear and longitudinal in FIG. **1**B as the first pipe joint **103** is not yet undergoing bending from reeling. The first internal liner section **123** is mechanically bonded to the inner surface **119** along a third length L**3**. The first length L**1**, the second length L**2**, and the third length L**3** are each linear and longitudinal. The first length L**1**, the second length L**2**, and the third length L**3** are each parallel to the longitudinal axis **121** and the minimum weld overlay length **115** that is illustrated as linear and longitudinal in FIG. **1**B.

The present disclosure contemplates that the second internal liner section **125** and the third internal liner section **127** may be weld overlaid at the same time. The present disclosure contemplates that one of the second internal liner section **125** or the third internal liner section **127** may be weld overlaid prior to weld overlaying of the other of second internal liner section **125** or the third internal liner section **127**.

In one embodiment, which can be combined with other embodiments, the corrosion resistant alloy of the first internal liner section **123**, the second section of alloy **125**, and/or the third internal liner section **127** includes one or more of the following materials: nickel, chromium, cobalt, titanium, iron, molybdenum, copper, niobium, tantalum, carbon, manganese, silicon, phosphorus, sulfur, and/or aluminum. The corrosion resistant alloy facilitates reduced or eliminated corrosion of the first pipe joint **103** while fluids (such as production fluids or injection fluids) flow through the first pipe **103** joint. In one embodiment, which can be combined with other embodiments, the corrosion resistant alloy of the first internal liner section **123**, the second section of alloy **125**, and/or the third internal liner section **127** includes stainless steel.

Weld overlaying the first length L**1** and the second length L**2** that are each greater than the minimum weld overlay length **115** facilitates reducing or preventing wrinkling of the first internal liner section **123** (which is mechanically lined) without requiring metallurgical bonding of the first internal liner section **123** to the inner surface. The risk of wrinkling of the first internal liner section **123** is reduced or eliminated during bending because the resultant deformation of the first pipe joint **103** corresponding to the third length L**3** during reeling is not exposed to increased deformation due to mismatch of properties between the first pipe joint **103** and an adjacent joint. Using the minimum weld overlay length **115** also facilitates preventing liner wrinkling and avoiding or reducing the use of: thicker pipes, thicker liners, internal pipe pressure while reeling, tighter pipe tolerances, and operations where re-reeling is prohibited. Hence, using the minimum weld overlay length **115** facilitates reducing or preventing liner wrinkling while facilitating benefits of reduced costs, reduced operational times, reduced operational difficulty, reduced vessel payload, and improved flow performance.

FIG. **2**A is a partial schematic view of a reeling system **200**, according to one implementation. The reeling system **200** is a reel-lay and spoolbase system. The reeling system **200** includes at least two regions, a first on-shore region **200**A and a second, adjacent, on-board region **200**B. The on-board region **200**B is on-board an offshore vessel **290**. The offshore vessel **290** is an installation vessel (e.g., a pipelay vessel). The first on-shore region **200**A includes a tie-in module **202** adjacent to an onshore tensioner **206** which can be adjacent to a joint coating station **210**. The tensioner **206** may also be installed on the offshore vessel **290**. Welding operations occur at the tie-in module **202**. In one example, welding of pipe joints together occurs at the tie-in module **202**. One or more on-shore (or onboard the offshore vessel **290**, as needed) rollers **212** (two are shown) may be employed to advance the pipe joints from the tie-in module **202**, the onshore tensioner **206**, and the joint coating station **210** and toward one or more on-board rollers **214** that are part of the on-board region **200**B.

FIG. **2**B is a partial schematic view of the offshore vessel **290** and spool **105** disposed thereon, illustrated in FIG. **2**A, during an offshore pipe-laying operation, according to one implementation. A pipeline **295** is unreeled from the spool **105** to pay out the pipeline **295** toward an oil and gas operations location, such as an oil and gas operations location on a seafloor **296**. The pipeline **295** is paid out by unloading (or unreeling) the pipeline **295** from the spool **105** disposed on the offshore vessel **290**. The pipeline **295** includes the pipe joints previously welded together and reeled onto the spool **105**. The pipeline **295** is unloaded from the spool **105** and fed over an aligner and through a tower **216** that may include a straightener and one or more tensioners.

FIG. **3** is a schematic view of a method **300** of making a lined pipe for reel-lay operations, according to one implementation. Operation **301** of the method **300** includes determining a minimum weld overlay length for a first pipe joint, and operation **303** includes positioning the first pipe joint for liner operations. The first pipe joint includes a first end opposite of a second end, a central opening, and an inner surface. Operation **305** includes disposing a first section of alloy in the central opening of the first pipe joint. Operation **307** includes mechanically lining the inner surface of the first pipe joint with the first section of alloy. Operation **309** includes weld overlaying a second section of alloy in the central opening of the first pipe joint and on a first side of the first section of alloy. The weld overlaying includes welding the second section of alloy to the inner surface of the first pipe joint along a first length that is greater than or equal to the minimum weld overlay length.

Benefits of the present disclosure include at least: ability to use re-reeling, reduced vessel payload, cost savings, time savings, improved flow performance, ease of operations, and reduced rejections of manufactured pipes for being outside of manufacturing tolerances.

Aspects of the present disclosure include at least: weld overlay lengths equal to or greater than a minimum weld length; determining a minimum weld length; simulating a resultant deformation (such as a resultant strain); and determining and using a threshold deformation (such as a threshold strain) to determine a minimum weld overlay length. It is contemplated that one or more of the aspects disclosed herein may be combined. Moreover, it is contemplated that one or more of these aspects may include some or all of the aforementioned benefits.

The present disclosure contemplates that the aspects described herein for the first pipe joint **103** may be implemented for the second pipe joint **101** and/or one or more additional pipe joints.

It will be appreciated by those skilled in the art that the preceding embodiments are exemplary and not limiting. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof. It is intended that all modifications, permutations, enhancements, equivalents, and improvements thereto that are apparent to those skilled in the art upon a reading of the specification and a study of the drawings are included within the scope of the disclosure. It is therefore intended that the following appended claims may include all such modifications, permutations, enhancements, equivalents, and improvements. The present disclosure also contemplates that one or more aspects of the embodiments described herein may be substituted in for one or more of the other aspects described.

We claim:

1. A method of making a lined pipe for reel-lay operations, comprising:

determining a weld overlay length for a first end and a second end of a first pipe joint based on bending properties of the first pipe joint, the weld overlay length configured to prevent wrinkle formation of the lined pipe;

positioning the first pipe joint for liner operations, the first pipe joint comprising the first end opposite of the second end of the first pipe joint, a central opening, and an inner surface;

disposing a first section of alloy in the central opening of the first pipe joint;

mechanically lining the inner surface of the first pipe joint with the first section of alloy;

weld overlaying a second section of alloy to the inner surface of the first end of the first pipe joint along a first length that is greater than or equal to the determined weld overlay length of the first end of the first pipe joint; and

weld overlaying a third section of alloy to the inner surface of the second end of the first pipe joint along a second length that is greater than or equal to the determined weld overlay length of the second end of the first pipe joint.

2. The method of claim **1**, further comprising welding the first end of the first pipe joint to a second end of a second pipe joint.

3. The method of claim **2**, further comprising reeling the first pipe joint and the second pipe joint onto a spool.

4. The method of claim **1**, wherein the first section of alloy, the second section of alloy, and the third section of alloy each comprises a corrosion resistant alloy.

5. The method of claim **4**, wherein the corrosion resistant alloy comprises one or more of stainless steel, nickel, chromium, cobalt, titanium, iron, molybdenum, copper, niobium, tantalum, carbon, manganese, silicon, phosphorus, sulfur, or aluminum.

6. The method of claim **1**, wherein the bending properties and a behavior of the first pipe joint are determined by simulating the bending of the first pipe joint using finite element analysis (FEA) software.

7. The method of claim **6**, wherein the simulating the bending of the first pipe joint is based on one or more parameters, and the one or more parameters include one or more of a spool diameter, a pipe inner diameter, a pipe outer diameter, a pipe length, a pipe material property, a liner material property, a straightener setting, a reeling tension, a reel back tension, a mechanical liner thickness, a mechanical liner length, or a weld overlay thickness, or a weld overlay length.

8. The method of claim **6**, wherein the simulating the bending of the first pipe joint comprises simulating a resultant deformation of the first pipe joint, and the determining the weld overlay length further comprises comparing the resultant deformation to a threshold deformation.

9. The method of claim **8**, wherein the weld overlay length of the first end and the second end are each a weld overlay length at which the resultant deformation is equal to or lesser than the threshold deformation.

10. The method of claim **1**, wherein the weld overlay length of the first end is different than the weld overlay length of the second end.

11. The method of claim **1**, wherein the welds of the second section of alloy and the third section of alloy abut the first section of alloy.

12. The method of claim **1**, wherein the welds of the second section of alloy and the third section of alloy are performed at the same time.

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